Airborne Microwave Radiometer Cloud Liquid Water Retrieval Validation and Examining Environmental Influences on Maritime Tropical Convection

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Introduction and Purpose

- NASA Cloud, Aerosol and Monsoon Processes Philippines Experiment (CAMP^{2}Ex), 20 Aug – 10 Oct 2019
  - Reid et al. (2023)
- Investigate aerosol-radiation-cloud interactions in the maritime tropics
- Suite of instrumentation deployed on NASA P-3 aircraft, including the Advanced Microwave Precipitation Radiometer (AMPR)

- Purpose of this study:

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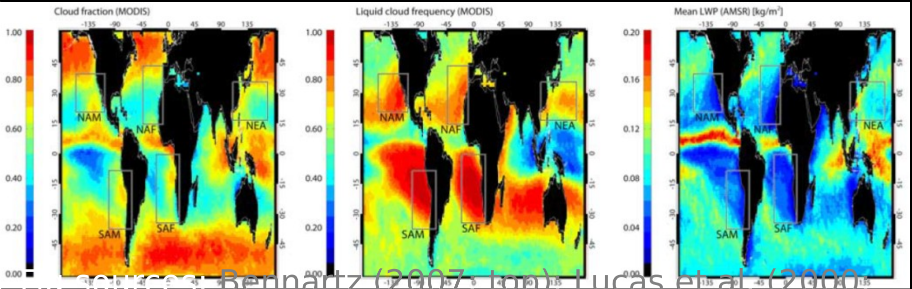
- Specific science questions for this presentation:

1) How do AMPR's tropical cloud liquid water retrievals compare with expectations and independent validation data?

2) How do variations in environmental

Literature Survey

- Accurate airborne geophysical retrievals using brightness temperatures (T_b) from microwave radiometers (e.g., Wilheit and Chang 1980; Yeh et al. 1990; Wentz 1997; Wentz and Meissner 2000; Hong and Shin 2013)
- AMPR (Spencer et al. 1994) cloud liquid water (CLW), water vapor, and 10-m wind speed retrievals developed for wintertime midlatitudes, results similar to expected uncertainties (Amiot et al. 2021)
- Cloud and rain liquid water content estimates from radar data, especially at finer wavelengths (e.g., Hagen and Yuter 2003; Oh et al. 2018)
- CLW correlated with satellite-retrieved cloud optical thickness and cloud droplet effective radius; CLW $\propto$ (CTH)^2 (Bennartz 2007; Miller et al. 2016)
  - CTH = cloud-top height
- <u>CLW target uncertainties</u>: 2.0×10^{-2} kg m^{-2} (Wentz and Meissner 2000); AMPR: ~0.1 kg m^{-2} (Amiot et al. 2021)



<u>Fig sources</u>: Bennartz (2007, top); Lucas et al. (2000, bottom)

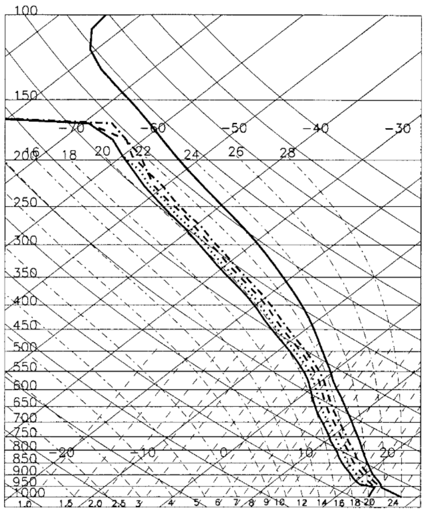
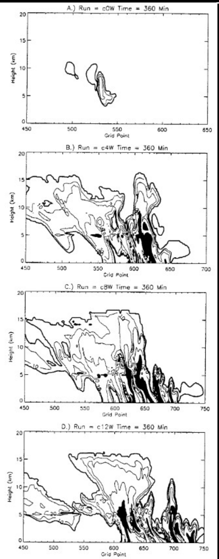


FIG. 1. The four thermodynamic profiles used in this study. Shown are c0 (solid), c4 (dotted), c8 (dashed), and c12 (dash–dot).



- Higher low-level water vapor and low-to-mid-level lapse rates may enhance convection, all else being equal (e.g., Lucas et al. 2000)

Data and Instrument Overviews

AMPR

- Advanced Microwave Precipitation Radiometer
- 50 cross-track pixels; scans ±45° from nadir
- T_b at 10.7, 19.35, 37.1, and 85.5 GHz
- Pure H and V polarized T_b via deconvolution
- CLW retrievals from combinations of 19.35, 37.1, and 85.5-GHz T_b data

APR-3

- Airborne Precip. & cloud Radar, 3rd Generation
- 25 cross-track pixels; scans ±25° from nadir
- 13.4 (Ku), 35.6 (Ka), and 94 GHz (W band)
- 30-m range resolution
- Ku- and Ka-band equivalent radar reflectivity factor (Z_H) and Doppler Velocity (V_r) used here

RSP

- Research Scanning Polarimeter
- Scans 105° along track; nadir data used here
- Radiance and scene polarization at nine spectral channels; 865 nm used here
- Cloud optical thickness (COT) and effective radius (r_e) inferred from the 865-nm data

AVAPS

- Advanced Vertical Atmos. Profiling System
- Dropsonde system
- Temperature, pressure, and humidity @ 2 Hz
- 144 dropsondes examined from flights 05–19
- 10 dropsondes discarded during data QC

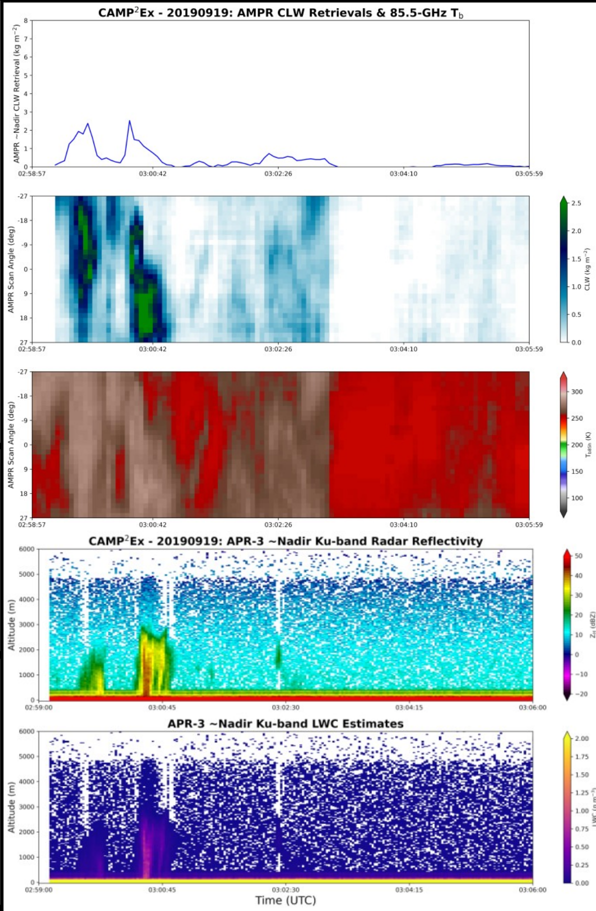
All data from joint CAMP²Ex-PISTON data

Analysis Methods

- Match AMPR and APR-3 data in time (repeated for RSP & AVAPS)
- Focus on comparing ~nadir AMPR CLW & co-located APR-3 CLW
- AMPR masks: HALF, nadir-stare, land, precipitation, scan edges
- APR-3 data remapped and filtered for noise prior to analysis
- Ku band: $W = 3.4z^{4/7}$, z in $mm^6\ m^{-3}$ (Hagen and Yuter 2003)
- Ka band: $W = (z/103.83)^{1/1.08}$, z in $mm^6\ m^{-3}$ (Oh et al. 2018)
- Integrate W to get columnar CLW ($kg\ m^{-2}$); calculate error statistics

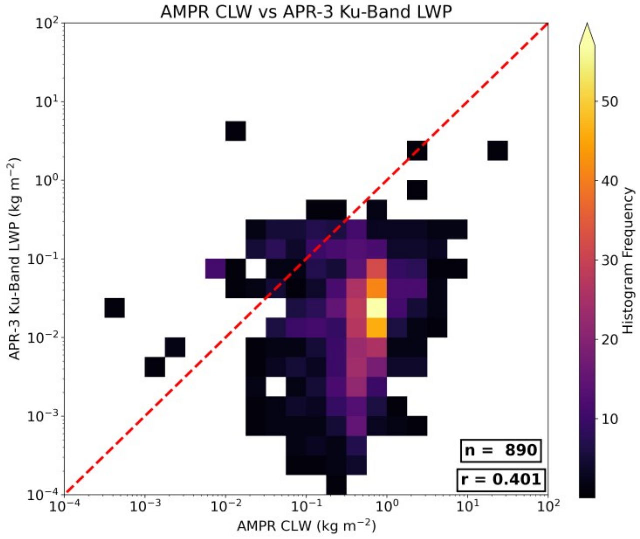
- RSP nadir 865-nm data matched in time with AMPR nadir CLW
- RSP CLW $= 5/9 \cdot \rho_w \cdot COT \cdot r_e$, r_e in m (Bennartz 2007; Miller et al. 2016)
- RSP-derived CTH and CLW compared with AMPR CLW

- AVAPS data analyzed on flight-by-flight basis and individually
- For latter, calculated: 700-hPa w, modified CAPE, K Index, LCL altitude, low- and mid-level lapse rates, and mean low-level T_d
- Compared with AMPR CLW and APR-3 Z_H (maximum, # > 30 dBZ)



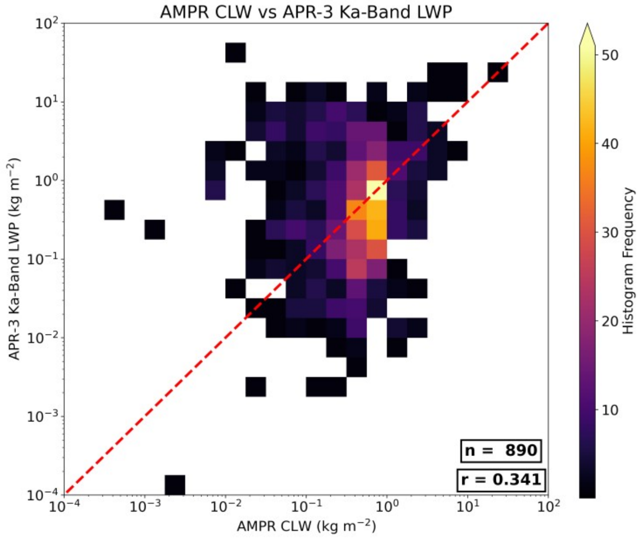
AMPR CLW Validation Results

Ku-Band APR-3



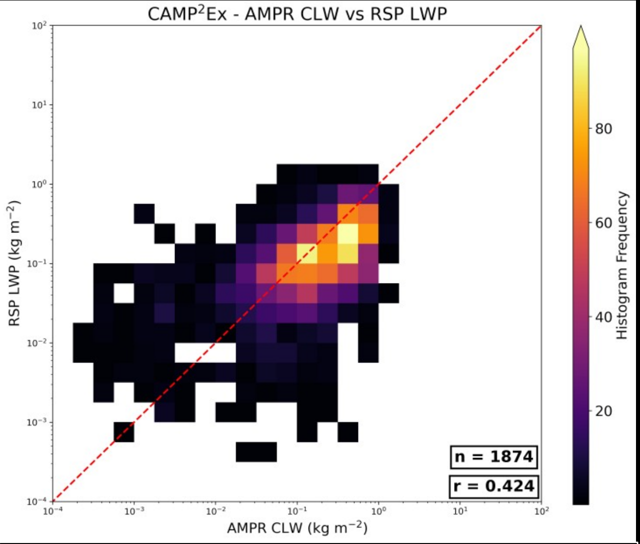
- **MedAE**: 0.410 kg m^{-2}
- **Percent Error**: 3.39 x 10^{3} %
- **Bias**: -0.155 kg m^{-2}

Ka-Band APR-3



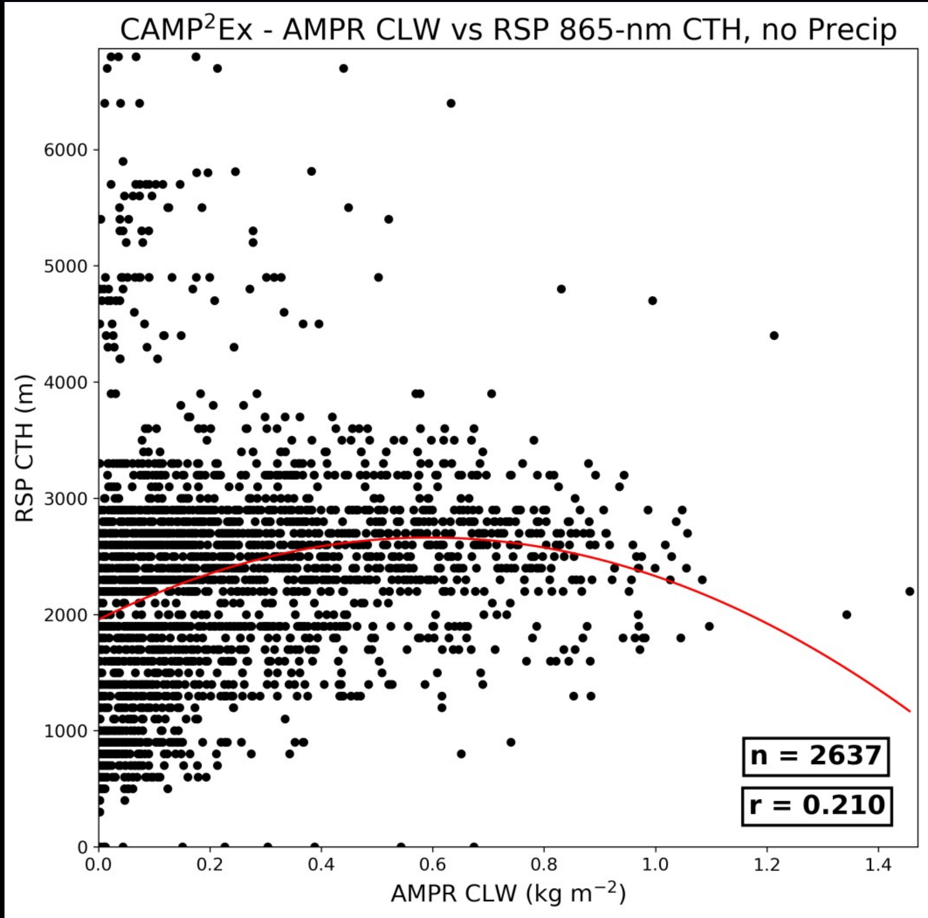
- **MedAE**: 0.432 kg m^{-2}
- **Percent Error**: 85.7%
- **Bias**: -7.02 x 10^{-2} kg m^{-2}

RSP



- **MedAE**: 8.08 x 10^{-2} kg m^{-2}
- **Percent Error**: 86.0%
- **Bias**: -3.28 x 10^{-2} kg m^{-2}

AMPR CLW versus RSP CTH

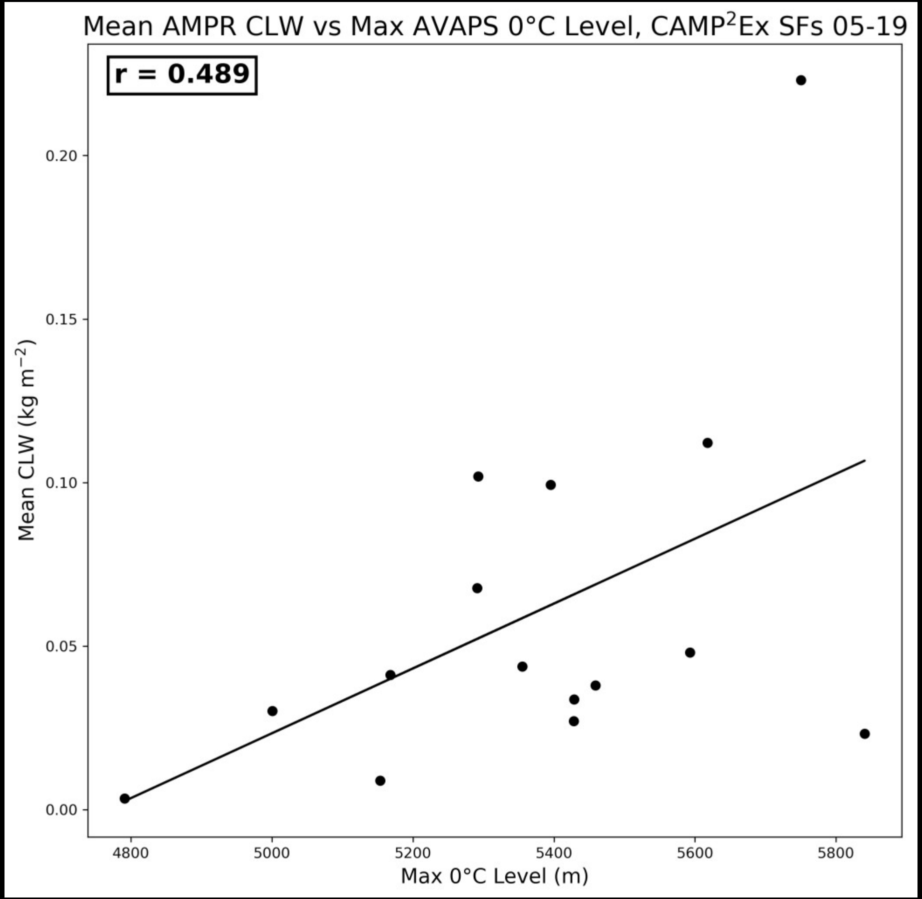


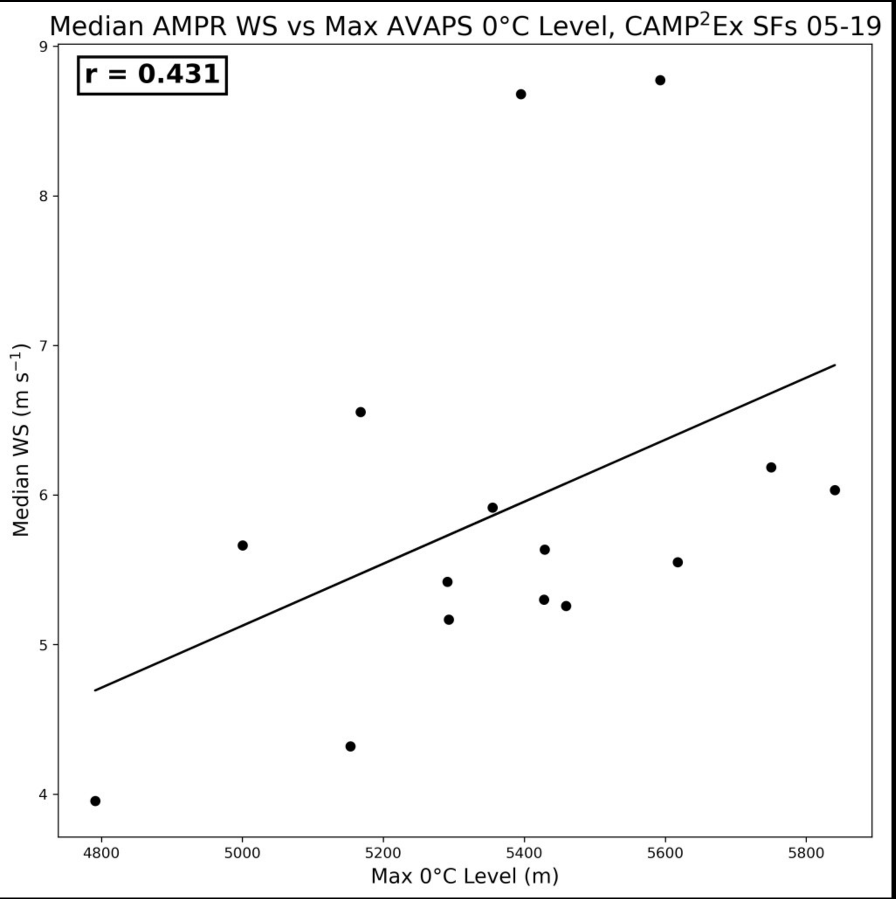
Clustering of low CLW values for CTH > 4 km

Anticipated CLW ∝ (CTH)² relation for CTH < 4 km

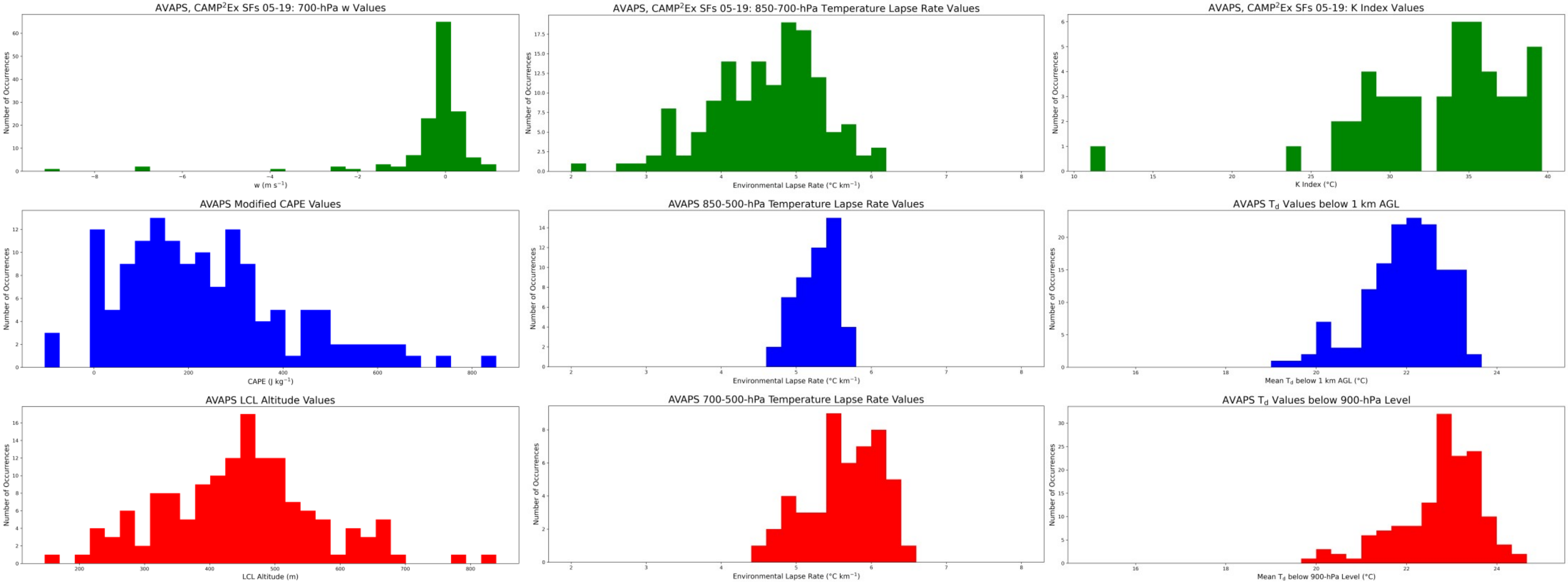
- AMPR CLW vs RSP CTH for all available precip-masked data points in CAMP²Ex flights 05–19
- Expected trends in CLW-CTH relation for CTH < 4 km AGL
- Sudden drop-off in CLW for CTH > 4 km
- Potentially indicative of accretion onset at CTH > 4 km, since rain data are largely excluded
- Perhaps influenced

Flight-by-Flight Dropsonde Results





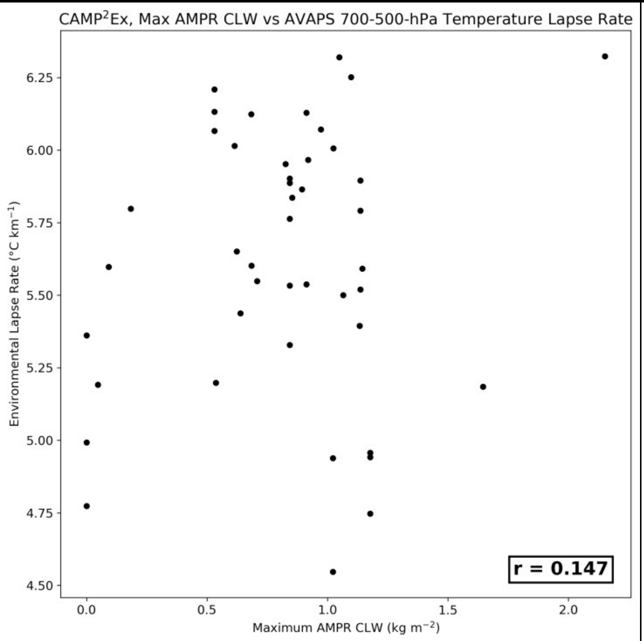
Overview of Derived AVAPS Values



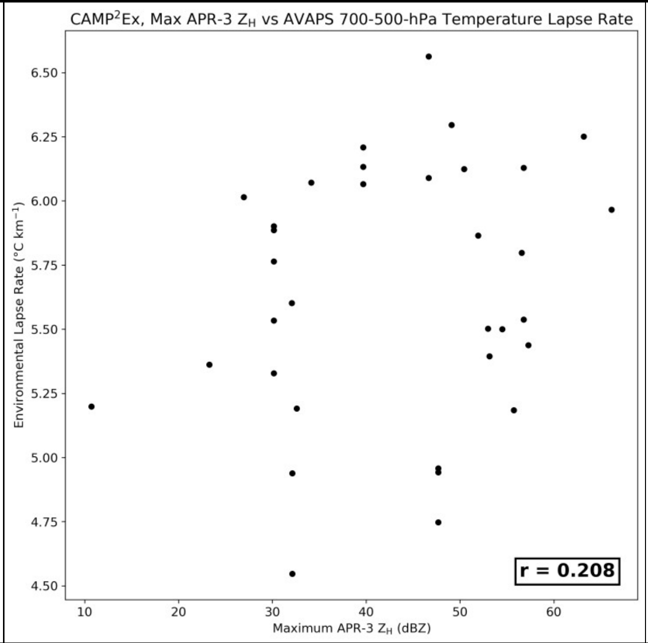
- <u>Greatest variation in</u>: modified CAPE, LCL altitude, 850–700-hPa lapse rate, and K Index
- Lapse rates (LRs) generally stable to conditionally unstable; low-level T_d nearly always

Individual Dropsondes vs AMPR & APR-3

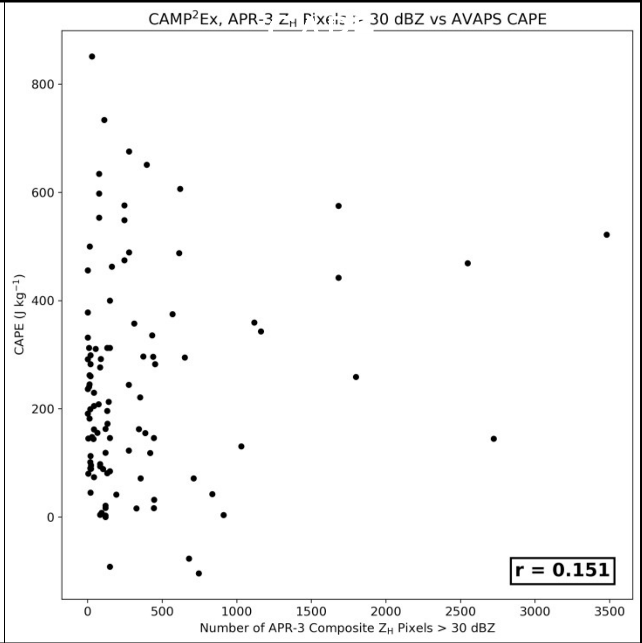
CLW vs 700–500-hPa LR



Max Z_H vs 700–500-hPa LR



Z_H > 30 dBZ vs Mod.



- Most other AVAPS-derived parameters yielded correlation coefficient near 0 or an unexpected negative correlation with AMPR CLW and/or APR-3 Z_H
  - Will be examined in greater detail as part of near-future work

Summary

- Study focused on AMPR tropical CLW retrievals, their validation, and comparisons with environmental data
- Favorable CLW error statistics with RSP (MedAD = 8.08×10^{-2} kg m^{-2}; percent error = 86.0%); generally higher errors when CLW compared with APR-3 (several limitations)
- CLW $\propto$ (CTH)^2 for CTH < 4 km, but clustering of lower CLW values for CTH > 4 km may indicate accretion onset
- Max AVAPS 0°C level moderately correlated with AMPR mean CLW and median WS
- 700–500-hPa weak direct correlation with max AMPR CLW and max APR-3 composite Z_H
- Modified CAPE weak direct correlation with # of APR-3 composite Z_H pixels > 30 dBZ

Future Work

- Investigate potential accretion identification from AMPR CLW / RSP CTH data further
- Revisit analysis of individual dropsondes, see if any stronger correlations can be found
- Evaluate other APR-3 and AMPR statistics and/or parameters (e.g., mean values for CLW and Z_H, water vapor and wind speed retrievals)
- Consider additional environmental parameters, (e.g., Total Totals Index, convective inhibition)
- RSP-AVAPS analyses
- Incorporate aerosol information (e.g., from airborne lidar) to examine potential influences on maritime tropical convection

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All data available at CAMP^{2}Ex-PISTON data repository:
https://www-air.larc.nasa.gov/cgi-bin/ArcView/camp2ex